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Published in:
Archives of Physical Medicine and Rehabilitation

DOI:
10.1016/j.apmr.2010.06.012

Publication date:
2010

ORIGINAL ARTICLE

Diagnostic Accuracy of History Taking and Physical Examination for Assessing Anterior Cruciate Ligament Lesions of the Knee in Primary Care

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ABSTRACT. Wagemakers HP, Luijsterburg PA, Boks SS, Heintjes EM, Berger MY, Verhaar JA, Koes BK, Bierma-Zeinstra SM. Diagnostic accuracy of history taking and physical examination for assessing anterior cruciate ligament lesions of the knee in primary care. Arch Phys Med Rehabil 2010;91:1452-9.

Objective: To assess the diagnostic accuracy of history taking and physical examination for assessing anterior cruciate ligament (ACL) lesions in primary care.

Design: Cross-sectional diagnostic study.

Setting: Primary care.

Participants: Patients (N=134; age, 18–65y) who consulted their general practitioner (GP) within 5 weeks after injury.

Interventions: Not applicable.

Main Outcome Measures: Index tests were obtained with a questionnaire and physical examination. Magnetic resonance imaging (MRI) was used as the reference test. Logistic regression analysis was used to determine associations with ACL lesions. Diagnostic accuracy was determined by calculating sensitivity (Se), specificity (Sp), predictive values, and likelihood ratio (LR).

Results: MRI showed an ACL lesion in 28 of 134 included patients. "Effusion," "popping sensation," "giving way," and "anterior drawer test (ADT)" showed associations with an ACL lesion ($P<.05$). Popping sensation showed Se, Sp, positive predictive value (PPV), and positive LR (LR^+) of .63, .73, .39, and 2.3, respectively. Combining determinants from history taking (2 of 3 positive results regarding effusion, popping sensation, and giving way) improved diagnostic accuracy (Se, .71; Sp, .71; PPV, .42; and LR^+, 2.5). The ADT added diagnostic accuracy to these combinations (Se, .63; Sp, .85; PPV, .52; and LR^+, 4.2).

Conclusions: ACL lesions are seen frequently. Based on history taking (effusion, popping sensation, and/or giving way) and physical examination (ADT), GPs can screen for ACL lesions in primary care.

Key Words: Anterior cruciate ligament; Diagnosis; Knee injuries; Primary health care; Rehabilitation.

A RUPTURE OF THE ANTERIOR cruciate ligament is a serious problem because of its role in controlling joint stability of the knee.[1] An ACL-deficient knee may result in such symptoms as pain, effusion, instability, and functional limitations in daily living, work, or sport.[2,3] Furthermore, ACL-deficient knees because of injury are considered to be an important risk factor for the development of osteoarthritis.[4,5] The incidence of knee injuries (excluding fractures) reported in Dutch primary care is about 5.3 per 1000 patients a year.[6] The prevalence of ACL injuries in the general population in the United States is estimated at 1 per 3500 persons.[7]

In patients consulting a GP for knee disorders caused by a knee injury, the GP uses history taking and physical examination to assess an initial diagnosis.[8,9] However, no studies of the diagnostic accuracy of history taking or physical examination in primary care patients are available. Three recent systematic reviews summarized the available knowledge concerning physical examination in diagnosing ACL lesions.[10-12] Scholten et al[10] (2003) reported that the pivot shift test has favorable PPV compared with the ADT and Lachman test. The Lachman test has good NPV, whereas the ADT seems of unproved value.[10] Jackson et al[11] concluded that the Lachman test is more sensitive and specific than the ADT. Based on 3 studies,[13-15] Solomon et al[12] stated that composite examination from history taking or physical examination for ACL lesions might increase the diagnostic value compared with specific items from history taking and physical examination. The conclusions from these 3 systematic reviews are based on studies concerning patients in the secondary care setting. Jackson[11] suggests a primary care setting in the title of the review; however, the review deals with only secondary care studies. In secondary care studies, arthroscopy often is used as the reference standard.

List of Abbreviations

ACL	anterior cruciate ligament
ADT	anterior drawer test
CI	confidence interval
GP	general practitioner
LR	likelihood ratio
LR^+	likelihood ratio positive
LR^-	likelihood ratio negative
MRI	magnetic resonance imaging
NPV	negative predictive value
PPV	positive predictive value
Se	sensitivity
Sp	specificity

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Supported by the health insurance companies Trias, Zilveren Kruis Achmea, and oz, with no role in the study design, conduct, or reporting.

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit on the authors or on any organization with which the authors are associated.

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0003-9993/10/9109-00250$36.00/0
doi:10.1016/j.apmr.2010.06.012

However, these studies carry the risk of verification bias, implying that ACL lesions are diagnosed by using arthroscopy only in patients highly suspected for having these lesions. For assessing the diagnostic value, the reference standard should be used in all patients with a knee injury, not only in those with highly suspected ACL lesions. Also, blinding between the index test and reference test was not performed in these studies.[16] The likelihood of actual lesions in a secondary care setting is expected to be higher because patient selection has already taken place.[16] In primary care, because selection has yet to take place, lower predictive values are expected.

Based on the initial diagnosis, GPs can decide on a "wait-and-see" policy, conservative treatment (eg, physical therapy), referral to secondary care for diagnostic imaging, or consultation with an orthopedic surgeon. About 25% of all patients with traumatic knee disorders who visit their GPs are referred to secondary care.[17] Furthermore, the initial diagnosis can serve to inform or reassure the patient. Because of the clinical decision making by the GP, an accurate diagnosis is important.

The purpose of this study is to determine the diagnostic value of history taking and physical examination for detecting ACL lesions in primary care. The study specifically aims to determine the diagnostic value of isolated tests and combinations of tests from history taking or physical examination in patients with ACL lesions. Our hypothesis is that combinations of tests have a higher diagnostic value than isolated tests. Also, we hypothesize that in patients with a complete ACL lesion, the diagnostic value is higher than with a partial ACL lesion. Because of the lack of knowledge about this issue in primary care settings, this study is of relevance to GPs.

METHODS

Design

The present cross-sectional diagnostic study was part of a large prospective observational cohort study of traumatic and nontraumatic knee symptoms in general practice.[18] More than 40 GPs from 5 municipalities in the southwest region of The Netherlands, participating in the Erasmus Medical Center GP research network HONEUR, asked patients with new knee symptoms to participate in the general cohort study. This network represents a total patient population of approximately 84,000 patients. Detailed information about the study design has been published elsewhere.[18]

From the general cohort study, patients were eligible for the diagnostic study if they were aged 18 to 65 years and had consulted their GP for knee symptoms within 5 weeks after a knee injury. In addition to participation in the general cohort study, these patients were asked for informed consent for additional MRI. Patients with MRI contraindications (pregnancy, metal implants, or a pacemaker) or suspected for a fracture were excluded from the present study. Finally, 134 patients participated in the present study.

The medical ethics committees of Erasmus Medical Center Rotterdam and Medical Center Rijnmond Zuid approved the study protocol.

Data Collection

During the initial consult with the GP, patients were informed about the diagnostic study. Patients who were willing to participate received a self-report questionnaire, and an appointment was made for MRI. This baseline questionnaire collected data about age; sex; socioeconomic status; history of previous knee injuries and/or operations; mechanism of injury; level of activity in work, household, and sports; the Lysholm knee score[19]; and pain severity.[20] Detailed information concerning the specific items in the questionnaire and categories of possible answers is given in Appendix 1.

Physical examination was carried out immediately after MRI according to a standardized protocol by a physical therapist (H.P.W.) with more than 15 years' experience in performing physical examination in patients with knee injuries and more than 10 years' experience in diagnostic research.[18] Physical examination of both knees consisted of inspection of alignment and assessment of joint effusion,[21] palpation of temperature,[21] palpation of the collateral ligaments,[21] and joint line tenderness,[21] assessment of effusion,[21,22] and passive range of motion in flexion and extension.[21,22] Cruciate and collateral ligament integrity were assessed by means of ADTs, posterior drawer tests,[23] the Lachman test,[24] pivot shift,[25] and valgus and varus stress tests.[26] Detailed information about test performances and the definition of a positive test result are given in Appendix 2.

There was no interference from the GP or the physical therapist who performed the examination with regard to the answers given by the patient in the questionnaire. The physical therapist was blinded for MRI results, as was the radiologist for results of physical examination and the questionnaire. Neither the patient nor the GP was informed about the outcome of MRI or physical examination; this was to avoid influencing patient behavior or management by the GP during follow-up.

MRI was selected as the reference test because it is a highly accurate diagnostic tool for detecting ACL lesions, especially complete lesions.[27,28] Partial lesions might be diagnosed less accurately by using MRI.[29,30] In the present study, MRI was scheduled 2 to 6 weeks after the initial trauma, using a 1.0-Tesla General Electric device.[a] Using this time frame, acute symptoms such as effusion or hemarthrosis likely will be reduced, whereas ACL lesions are still present.[31] Detailed information about the MRI procedure is reported elsewhere.[32]

Patient outcome was defined as the presence or absence of a complete or partial ACL lesion as seen on MRI. Two radiologists classified the MRI scans independently of each other.[32]

Statistical Analysis

Descriptive statistics were used to present results of MRI. Binary logistic regression analysis (SPSS[b]) was used to determine the association of separate determinants from history taking and physical examination with ACL lesions, expressed as odds ratios. Determinants showing a bivariate association with an ACL lesion ($P<.15$) were analyzed in a multivariate logistic regression analysis (backward Wald method, entry $P=.10$, removal $P=.20$) to eliminate redundant variables. Separate analyses were performed for history taking and physical examination. We used a cutoff point (arbitrarily) of $P=.15$ for initial inclusion in the multivariate model because this cutoff point is favorable when analyzing dichotomized determinants.[33] Finally, the remaining determinants were analyzed together (using the Enter method) to compose a diagnostic model for ACL lesions ($P<.05$).

It is reported that complete ACL lesions are diagnosed accurately by using MRI,[27,28] whereas partial ACL lesions might be diagnosed less accurately by using MRI.[29,30] Because GPs see patients presenting with both partial and complete ACL lesions and a management decision might differ depending on the nature of the involved lesion, we performed an analysis including patients with a partial or complete ACL lesion and a subgroup analysis including only patients with complete ACL lesions.

The diagnostic value of the determinants from the diagnostic model for ACL lesions was determined by calculating Se, Sp, PPV, and NPV.[34] We also determined LR for positive (LR^+)

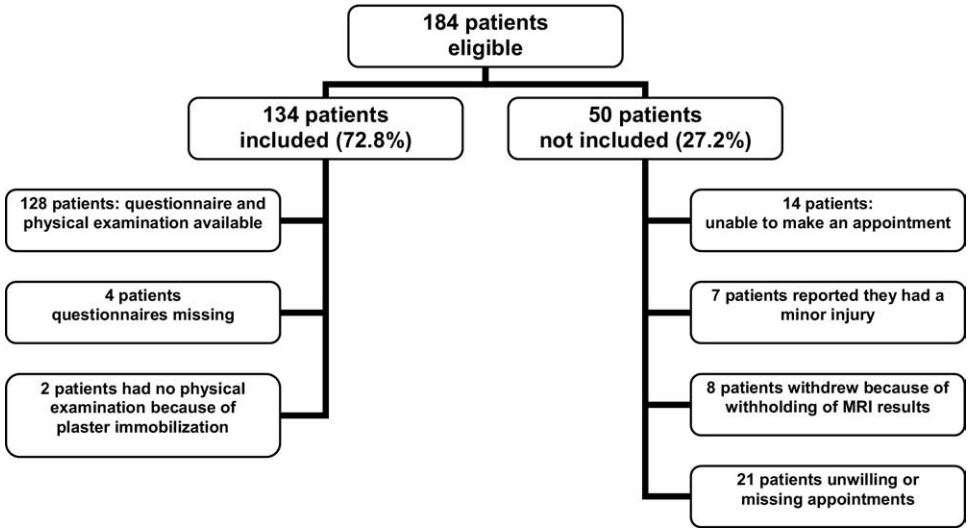

Fig 1. Flow chart of eligible patients.

and negative (LR^-) examination results.[34] In general, an LR^+ of 1 to 2 or LR^- of .5 to 1 alters the probability of the presence or absence of an ACL lesion by only a small degree.[35] An LR^+ of 2 to 10 or LR^- of 0.5 to 0.1 may be considered clinically important.[35] An LR^+ greater than 10 or LR^- less than 0.1 may have substantial impact on the probability of the diagnosis.[34]

We also determined the diagnostic value for combinations of specific determinants from the diagnostic model. We first combined determinants from history taking, then added determinant(s) from physical examination in the diagnostic model.

RESULTS

Study Population

Patients (N=184) were referred for the present diagnostic study during the inclusion period of 18 months. Of these patients, 134 (73%) were included (fig 1). Reasons for nonparticipation of the other 50 patients were unwillingness after extended information about the research protocol or missing appointments for MRI (n=21), inability by the patient to find time for the MRI appointment (n=14), too minor injury according to the patient (n=7), and no informed consent because of withholding MRI results from the patient and GP (n=8). No patient was excluded because of MRI exclusion criteria or a diagnosed fracture.

No clinical or demographic significant differences were found between baseline characteristics of participants and nonparticipants. Table 1 lists baseline characteristics of participants. Mean age of participants was 40 years (range, 18–64y), and a small majority were men (55.2%). A total of 61 (45.5%) patients reported that sport activities were the cause of the sustained knee injury. At baseline, mean pain severity (measured using a numerical rating scale) was 4.7 (0=no pain to 10=unbearable pain), and mean Lysholm knee score was 62.0 (0=worse to 100=best).

MRI Results

Results of MRI are listed in table 1. Average time between trauma and MRI was 38 days (range, 9–81); 70% of all patients had MRI performed within 6 weeks after the initial trauma. Fourteen (10.4%) patients showed no effusion, ligamentous lesions, or meniscal tears on MRI, and 38 (28.4%) showed only effusion without detectable ligamentous lesions or meniscal tears. Thus, 52 patients (38.8%) had no signs of meniscal tears or ligamentous lesions.

ACL lesions detected by using MRI were seen in 28 of 134 included patients (21%); 11 lesions were partial and 17 lesions were complete.

History Taking and Physical Examination

In 128 (95.5%) patients, both history taking and physical examination were available. Questionnaires were available for 130 (97.0%) patients. Four questionnaires were not returned by the patient (fig 1). Physical examination was performed in 132 (98.5%) patients; 2 patients had plaster immobilization at the time of MRI.

Table 1: Patient Characteristics and Findings on MRI

Patient Characteristics	
Age (y)	40.2±12.2
Men	74 (55)
Onset during sports activity	61 (45)
Symptom side right	70 (52)
Pain severity (0–10)	4.7±2.4
Lysholm knee function score (0–100)	62±19
Diagnosis as seen on MRI	
No lesion or effusion	14 (10)
Contusion (effusion, no ligament or meniscal lesion)	38 (28)
ACL lesion	28 (21)
Partial lesion	11 (8)
Complete lesion	17 (13)
Posterior cruciate ligament lesion	6 (4)
Meniscal tear	47 (35)
Medial collateral ligament lesion	35 (26)
Lateral collateral ligament lesion	8 (6)
ACL lesion and meniscal tear	15 (11)

NOTE. Values expressed as mean ± SD or n (%) unless noted otherwise.

Table 2: Bivariate Association With ACL Lesions

Variables	Patients Available (n)	Partial and Complete ACL Lesions (n=28)	P	Complete ACL Lesions (n=17)	P
History taking					
Signs at injury					
"Popping" sensation	126	4.5 (1.8–11.1)	.001	4.2 (1.4–12.4)	.009
Continuation of activity impossible	126	3.8 (1.5–9.6)	.006	3.6 (1.1–11.8)	.033
Immediate pain at trauma	126	8.2 (1.0–63.8)	.043	4.3 (0.5–33.9)	.169
Present symptoms					
Effusion (continuous)	127	2.0 (0.9–4.8)	.111	3.0 (1.1–8.6)	.036
Lysholm knee score <80	130	2.9 (0.8–10.2)	.108	1.4 (0.4–5.2)	.622
Giving way (Lysholm)[19]	130	2.6 (1.1–6.1)	.029	2.9 (1.0–8.3)	
Physical examination					
Pain palpation MCL	130	1.9 (0.8–4.8)	.136	2.3 (0.8–6.9)	.052
Pain at passive flexion	130	3.0 (1.1–8.6)	.038	2.8 (0.8–10.3)	.144
Pain passive extension	130	2.0 (0.9–4.8)	.111	2.8 (0.8–10.3)	.119
Laxity valgus stress test 0°	120	3.1 (1.2–8.1)	.019	1.4 (0.5–4.1)	.478
Laxity valgus stress test 30°	127	3.3 (1.2–9.5)	.025	1.4 (0.4–4.6)	.553
Laxity ADT	127	6.7 (2.1–21.0)	.001	8.5 (1.8–39.4)	.006
Laxity Lachman test	127	3.6 (1.3–10.4)	.016	2.9 (0.9–8.7)	.104
Effusion fossa poplitea	130	3.3 (1.1–10.3)	.040	2.6 (0.7–9.4)	.159

NOTE. Values expressed as odds ratio (95% CI) or (n).
Abbreviation: MCL, medial collateral ligament.

After bivariate analysis, 10 determinants showed a statistically significant association with a partial or complete ACL lesion ($P<.05$). All determinants resulted in a higher probability of an ACL lesion when found positive. Four of these 10 determinants were obtained from history taking, including "continuation of activity impossible," "immediate pain at trauma," "popping sensation during trauma," and "giving way (Lysholm score)." The remaining 6 determinants were obtained from physical examination, including "pain at passive flexion," "laxity valgus stress 0°," laxity valgus stress 30°," "laxity ADT," "laxity Lachman test," and "effusion fossa poplitea" (table 2).

After multivariate modeling, the determinants "effusion," "popping sensation," "giving way," and "laxity ADT" showed a significant association ($P<.05$) with the presence of a partial or complete ACL lesion (table 3). All 4 variables increased the probability of an ACL lesion when found positive.

Bivariate analysis of the subgroup with only complete ACL lesions showed 8 determinants with a statistically significant association ($P<.15$), including "popping sensation during trauma," "continuation of activity impossible," "effusion," "giving way (Lysholm score)," "pain palpation medial collateral ligament," "pain at passive flexion," "laxity ADT," and "laxity Lachman test" (see table 2). After multivariate modeling, the diagnostic model resulted in the same determinants as in the group with partial or complete ACL lesions (see table 3).

Table 3: Multivariate Association With ACL Lesions

Variable	Partial or Complete ACL Lesion* (n=28)	Complete ACL Lesion* (n=17)
History taking		
Effusion (continuous)	4.4† (1.4–14.5)	6.1† (1.6–23.0)
"Popping" sensation at trauma	6.1† (1.9–19.5)	4.8† (1.3–18.3)
Giving way (Lysholm)	3.5† (1.1–10.9)	3.7† (1.0–13.8)
Physical examination		
ADT	6.4† (1.8–23.0)	8.8† (1.7–45.8)
Explained variance (%)	41	40

NOTE. Values expressed as odds ratio (95% CI) unless noted otherwise.
*As detected using MRI.
†$P<.05$.

Diagnostic Value of History Taking and Physical Examination

In this study population, the prevalence of a partial or complete ACL lesion was .21, and of a complete ACL lesion, .13. Se, Sp, PPV, NPV, and LRs (LR^+ and LR^-) are listed in table 4. After the diagnostic workup, precision to predict an ACL lesion (PPV) increased from .21 to .39 (95% CI, .24–.53) with a positive "popping sensation during trauma." A positive ADT had Se, Sp, and PPV of .83 (95% CI, .68–.98), .57 (95% CI, .48–.67), and .31 (95% CI, .20–.43), respectively. Precision to predict the absence of an ACL lesion (NPV) increased from .79 to .88 (95% CI, .81–.95) with a negative "popping sensation during trauma" and to .94 (95% CI, .88–1.00) with a negative ADT. LRs of a positive "popping sensation during trauma" (LR^+) were 2.3 (95% CI, 1.5–3.6) and 2.0 (95% CI, 1.5–2.6) for a positive ADT. The LR of a negative ADT (LR^-) was 0.3 (95% CI, 0.1–0.7).

We also combined determinants from the diagnostic model for assessing ACL lesions (table 3). When at least 2 of 3 items from history taking scored positive, precision to predict an ACL lesion (PPV) was .42 (95% CI, .28–.56), Se was .71 (95% CI, .55–.88), and Sp was .71 (95% CI, .62–.80). A negative score resulted in prediction of the absence of an ACL lesion (NPV) of .90 (95% CI, .83–.96). All 3 items positive resulted in Se of .18 (95% CI, .04–.32), Sp of .99 (95% CI, .98–1.00), PPV of .83 (95% CI, .66–1.00), and NPV of .81 (95% CI, .74–.88). Adding the result of the ADT to the combinations mentioned resulted in Se of .63 (95% CI, .43–.82), Sp of .85 (95% CI, .78–.92), PPV of 0.52 (95% CI, .34–.70), and NPV of .90 (95% CI, .84–.96). Adding the ADT to the combination of all 3 items positive from history taking, Se decreased to .16 (95% CI, .02–.30), Sp increased to .99 (95% CI, .98–1.00), PPV increased to .80 (95% CI, .60–1.00), and NPV decreased

Table 4: Diagnostic Values and 95% CIs of Isolated Determinants and Combinations of Determinants With ACL Lesions

Variable	n	Se	Sp	PVP	PVN	LR^+	LR^-
Partial and complete ACL lesions (n=28; prevalence=.21)							
History taking							
Effusion	39	0.43 (0.25–0.61)	0.73 (0.64–0.82)	0.31 (0.16–0.45)	0.82 (0.74–0.90)	1.6 (0.9–2.7)	0.8 (0.6–1.0)
"Popping" sensation	44	0.63 (0.45–0.81)	0.73 (0.64–0.82)	0.39 (0.24–0.53)	0.88 (0.81–0.95)	2.3 (1.5–3.6)	0.5 (0.3–0.8)
Giving way	55	0.61 (0.43–0.79)	0.63 (0.53–0.67)	0.31 (0.19–0.43)	0.85 (0.77–0.93)	1.6 (1.1–2.4)	0.6 (0.4–1.0)
Physical examination							
ADT	64	0.83 (0.68–0.98)	0.57 (0.48–0.67)	0.31 (0.20–0.43)	0.94 (0.88–1.00)	2.0 (1.5–2.6)	0.3 (0.1–0.7)
Combinations							
History≥1+	93	1.00 (1.00–1.00)	0.23 (0.15–0.32)	0.27 (0.18–0.35)	1.00 (1.00–1.00)	1.3 (1.2–1.5)	0.0
History≥2+	41	0.71 (0.55–0.88)	0.71 (0.62–0.80)	0.42 (0.28–0.56)	0.90 (0.83–0.96)	2.5 (1.7–3.7)	0.4 (0.2–0.7)
History=3+	5	0.18 (0.04–0.32)	0.99 (0.98–1.00)	0.83 (0.66–1.00)	0.81 (0.74–0.88)	17.7 (2.2–145.0)	0.8 (0.7–1.0)
History≥1+/ADT+	47	0.83 (0.68–0.98)	0.64 (0.54–0.73)	0.36 (0.24–0.49)	0.94 (0.88–1.00)	2.3 (1.7–3.2)	0.3 (0.1–0.6)
History≥2+/ADT+	21	0.63 (0.43–0.82)	0.85 (0.78–0.92)	0.52 (0.34–0.70)	0.90 (0.84–0.96)	4.2 (2.4–7.5)	0.4 (0.3–0.7)
History=3+/ADT+	4	0.16 (0.02–0.30)	0.99 (0.98–1.00)	0.80 (0.60–1.00)	0.82 (0.75–0.89)	15.4 (1.8–131.0)	0.8 (0.7–1.0)
Complete ACL lesions (n=17; prevalence=.13)							
History taking							
Effusion	39	0.53 (0.29–0.77)	0.73 (0.65–0.81)	0.23 (0.10–0.36)	0.91 (0.85–0.97)	2.0 (1.1–3.4)	0.6 (0.4–1.0)
"Popping" sensation	44	0.65 (0.42–0.87)	0.70 (0.61–0.78)	0.25 (0.12–0.38)	0.93 (0.87–0.98)	2.1 (1.4–3.4)	0.5 (0.3–1.0)
Giving way	55	0.65 (0.42–0.87)	0.61 (0.52–0.70)	0.20 (0.09–0.31)	0.92 (0.86–0.98)	1.7 (1.1–2.5)	0.6 (0.3–1.1)
Physical examination							
ADT	64	0.88 (0.71–1.00)	0.55 (0.46–0.64)	0.22 (0.12–0.32)	0.97 (0.92–1.00)	1.9 (1.5–2.6)	0.2 (0.1–0.8)
Combinations							
History≥1+	93	0.88 (0.73–1.00)	0.31 (0.22–0.39)	0.16 (0.09–0.24)	0.95 (0.87–1.00)	1.3 (1.0–1.6)	0.4 (0.1–1.0)
History≥2+	41	0.76 (0.56–0.97)	0.75 (0.67–0.83)	0.32 (0.17–0.46)	0.95 (0.91–1.00)	3.1 (2.0–4.6)	0.3 (0.1–0.7)
History=3+	5	0.18 (0.00–0.36)	0.98 (0.96–1.00)	0.60 (0.17–1.00)	0.89 (0.83–0.94)	9.8 (1.8–54.4)	0.8 (0.7–1.0)
History≥1+/ADT+	47	0.81 (0.62–1.00)	0.69 (0.60–0.77)	0.28 (0.15–0.40)	0.96 (0.92–1.00)	2.6 (1.8–3.7)	0.3 (0.1–0.8)
History≥2+/ADT+	27	0.65 (0.42–0.87)	0.91 (0.86–0.96)	0.52 (0.31–0.74)	0.94 (0.90–0.99)	7.2 (3.6–14.4)	0.4 (0.2–0.7)
History=3+/ADT+	4	0.19 (0.00–0.38)	0.99 (0.98–1.00)	0.75 (0.50–1.00)	0.89 (0.83–0.95)	19.9 (2.2–179.6)	0.8 (0.6–1.0)

Abbreviation: n, prevalence of the determinant or combination.

to .82 (95% CI, .75–.89). The likelihood of 2 of 3 items positive (LR^+) was 2.5 (95% CI, 1.7–3.7), and 0.4 (95% CI, 0.2–0.7) with 2 or 3 items negative (LR^-). Adding the ADT to this combination, LR^+ and LR^- became 4.2 (95% CI, 2.4–7.5) and 0.4 (95% CI, 0.3–0.7), respectively. In the subgroup with complete ACL lesions, overall, PPV was lower than in the subgroup with partial and complete ACL lesions (table 4).

DISCUSSION

The present study is the first to investigate the diagnostic value of history taking and physical examination in patients with an ACL lesion in a primary care setting. The injuries of the included patients ranged from no abnormalities at the time of MRI to complete ACL lesions in combination with meniscal tears and collateral ligament lesions; an ACL lesion was seen in 21% of these patients.

Our results show the diagnostic value of isolated determinants from history taking in detecting ACL lesions, especially "popping sensation during trauma." A positive ADT result obtained from physical examination has less diagnostic value. However, a negative ADT result has higher diagnostic value compared with history taking. However, combining the ADT with determinants from history taking adds little to the diagnostic value. Therefore, both isolated determinants, "popping sensation during trauma" and ADT, are diagnostic tools for GPs in predicting the presence or absence of an ACL lesion.

The systematic review of Scholten et al[10] reported that the pivot shift test was preferable to the ADT or Lachman test. The Lachman test is considered most useful to detect anterior-posterior instability caused by ruptures of the anterior-medial bundle of the ACL, whereas the pivot shift test is believed to be more valuable to detect rotational instability caused by ruptures of the posterior-lateral bundle. However, in our study population, this pivot shift test was performed in the acute phase after the injury in only 98 patients; in 32 patients, pain hindered performance of this test. This phenomenon clearly shows a difference in results from studies in primary and secondary care settings, more specifically regarding the moment of examination (acute vs late phase after injury). Both Scholten[10] and Jackson et al[11] reported that the Lachman test is preferable to the ADT. In our study, both the Lachman test and ADT show an almost equal association with ACL lesions and correlated highly (not reported). In multivariate analysis, only the ADT remained in the model; however, the diagnostic value is very similar. The Lachman test is equally useful in clinical practice, especially for those who are more acquainted with this test than with the ADT or prefer this test to the ADT.

In the present study, composite examination increased the diagnostic value as hypothesized. This finding is in line with expectation reported by Solomon et al.[12]

When all 4 items from the diagnostic model are positive, the diagnosis of ACL lesion can be made with reasonable (ie, 80%) certainty (table 4). However, this applies to very few cases. With at least 2 of the 3 items from history taking positive and a positive ADT result (which applies to many more cases), the probability of an ACL lesion is doubled, but it is still only 52%. If no item from history taking is positive, an ACL lesion can be excluded, which again only applies to a few cases. In case of a

negative ADT result, there is only a 6% probability of having an ACL lesion, and this applies to 50% of the present cases.

Based on our results, GPs can reasonably exclude ACL lesions mainly by history taking, which is important to reassure the patient and argue against further diagnostic and therapeutic interventions. This strategy may avoid unnecessary restriction of daily activities and/or use of health care resources.

In the present study, the determinants "weight bearing during trauma" and "ballottement" almost reached the cutoff point of .15. With a larger study population, these determinants might have been included in the final model. In addition, results of the present study preferably should be validated in another study in primary care including a similar study population of patients consulting for acute traumatic knee disorders.

Study Limitations

Some limitations of the present study need to be addressed. History taking was obtained by using a questionnaire and not a face-to-face interview. Because of the need for standardization and the number of items asked, we used a questionnaire. Although this does not represent daily practice, we expect that results are not influenced by doing so. Furthermore, patients may not have ACL lesions alone. In our study, 15 patients had an ACL lesion and a meniscal tear. It has been reported that the accuracy of clinical examination of ACL lesions with associated lesions is reduced compared with isolated ACL lesions.[36] In our statistical analysis, we corrected for meniscal tears and saw no significant alterations in the diagnostic model. Furthermore, we included fewer than 10 events per covariate, which could have resulted in biased estimates and over- or underestimated variances. Another limitation is that MRI is considered to be less accurate in detecting partial ACL lesions.[29,30]

Because a management decision might differ depending on whether the ACL lesion is partial or complete, we performed subgroup analysis including only complete ACL lesions. These results showed no clear difference in diagnostic value compared with the combined group of ACL lesions.

CONCLUSIONS

ACL lesions are seen frequently. Based on history taking (effusion, popping sensation, and/or giving way) and physical examination (ADT), GPs can screen for ACL lesions in primary care.

In addition, more prospective observational and experimental studies of the treatment and prognosis of ACL lesions (including cost-effectiveness analysis) are recommended.

APPENDIX 1: ITEMS FROM HISTORY TAKING ANALYZED FOR ASSOCIATION WITH ACL LESIONS[18]

Variable	Description of Question Asked	Positive Result
Demographics		
Age	Date of birth in years	Positive if age >40y
Sex	Man or woman	Positive if sex is male
Mechanism of injury		
Fall on the knee	Did you fall on your knee? (yes/no/do not remember*)	Positive if yes
Injury by external force to knee	Was there an external force to your knee due to a kick, bang, or knock? (yes/no/do not remember*)	Positive if yes
Injury while landing on leg	Did the injury happen when landing on your leg? (yes/no/do not remember*)	Positive if yes
Weight bearing on knee during injury	Was your knee bearing weight during the injury? (yes/no/do not remember*)	Positive if yes
Rotational injury	Did you twist your knee during the injury by twisting your body compared with the position of your leg? (yes/no/do not remember*)	Positive if yes
Foot/leg blocked	Was your foot/leg blocked during the injury? (yes/no/do not remember*)	Positive if yes
"Popping" sensation	Did you hear or feel a "popping" sensation during the injury? (yes/no/do not remember*)	Positive if yes
Signs at injury		
Continuation of activity impossible	Was it possible for you to continue your activities for some time after the injury by continuing the game, assignment, etc? (yes/no)	Positive if yes
Immediate pain at injury	When did the pain develop after the injury? (not at all/immediately/after some hours/within 24h/after 24h)	Positive if the pain developed immediately after the injury
Immediate effusion after injury	When did the swelling develop after the injury? (not at all/within 2h after the injury/>2h after the injury but within 24h)	Positive if the swelling developed within 2h after the injury
Present symptoms		
Pain score	Numerical rating scale (0–10) for severity of pain	Positive if numerical rating scale pain score is ≥6
Lysholm score <80[19]	Scoring list of 9 questions	Positive if Lysholm score <80
Effusion	Does your knee feel swollen? (no/sometimes/all the time)	Positive if knee feels swollen all the time
Crepitation	Do your feel/hear a crack inside the knee? (no/sometimes/all the time)	Positive if hear crack all the time
Warm knee	Does your knee feel warm? (no/sometimes/all the time)	Positive if knee feels warm all the time

*When the answer was "do not remember," the variable was defined as missing.

APPENDIX 2: ITEMS FROM THE PHYSICAL EXAMINATION FOR ASSOCIATION WITH AN ACL LESION

Variable[reference]	Description of a Positive Test Result
Genu flexum[20]	Positive if the knee is in flexed position during weight bearing
Increased temperature[20]	Positive if the same or increased temperature of the knee is felt by the examiner compared with the adjacent thigh/lower leg
Ballottement test[20]	Positive if the patella strikes the trochlea with a distinct impact or flows back to its former position when the examiner pushes the patient's patella posteriorly with 2 or 3 fingers using a quick sharp motion
Minor effusion test (fluctuation)[20]	Positive if, after the examiner milks the fluid from the suprapatellar pouch and lateral side into the medial side of the knee (extended knee) and gently taps the joint over the fluid, the fluid traverses the knee and creates fullness on the lateral side
Pain palpation medial joint line[20]	Positive if pain is felt when the examiner palpates the medial part of the anterior joint line of the flexed knee (90°)
Pain palpation lateral joint line[20]	Positive if pain is felt when the examiner palpates the lateral part of the anterior joint line of the flexed knee (90°)
Pain palpation MCL[20]	Positive if pain is felt when the examiner palpates the MCL of the slightly flexed knee
Pain palpation LCL[20]	Positive if pain is felt when the examiner palpates the LCL of the flexed knee (90°) with the hip in external rotation and abduction
Pain at passive flexion[21]	Positive if pain is felt when the knee is gently forced in full flexion by the examiner
Pain at passive extension[21]	Positive if pain is felt when the knee is gently forced in full extension (hyperextension) by the examiner
Laxity varus stress 0° test[22]	Positive if increased laxity is felt by the examiner when the extended knee is forced in varus
Laxity valgus stress 0° test[22]	Positive if increased laxity is felt by the examiner, palpating the medial joint space, when the extended knee is forced in valgus
Laxity varus stress 30° test[22]	Positive if increased laxity is felt by the examiner when the 30° flexed knee is forced in varus
Laxity valgus stress 30° test[22]	Positive if increased laxity is felt by the examiner, palpating the medial joint space, when the 30° flexed knee is forced in valgus
Laxity ADT[22]	Positive if essentially more laxity is felt compared with the other knee in the 45° flexed knee (with hip 90° flexed and the foot fixed by the examiner sitting on it) when the examiner gently translates the proximal tibia forward with both his/her hands
Laxity posterior drawer[22]	Positive if essentially more laxity is felt compared with the other knee in the 45° flexed knee (with hip 90° flexed and the foot fixed by the examiner sitting on it) when the examiner gently translates the proximal tibia backward with both his/her hands
Laxity Lachman test[23]	Positive if essentially more laxity is felt in the slightly flexed (20°) knee than when the proximal tibia is translated forward with 1 hand of the examiner while the distal part of the femur is fixed by the other hand
Pivot shift test[24]	Positive if subluxation by the tibiae occurs during internal rotation
Effusion popliteal fossa[20]	Positive if the examiner judges that there is effusion and/or Baker cyst during palpation in the fossa of the extended knee

Abbreviations: LCL, lateral collateral ligament; MCL, medial collateral ligament.

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Suppliers

a. General Electric, 5486 North Lake Dr, Milwaukee, WI 53217-5374.
b. SPSS, version 11.0; SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.